

## Economics of irrigation: introduction

The “Agricultural Economics” section of this SJAR 9(4) issue compiles a selection of thirteen articles on the economics of irrigation that analyse some of the most relevant issues related to water use in Mediterranean agricultural systems. The relevance of economics for the management of water resources in irrigated agriculture arises from the fact that water is the most limiting factor for agricultural production in arid and semi-arid regions. Moreover, basins and catchments are closely interrelated systems where a change in any component necessarily has consequences elsewhere or to others as positive or negative externalities that have important economic implications.

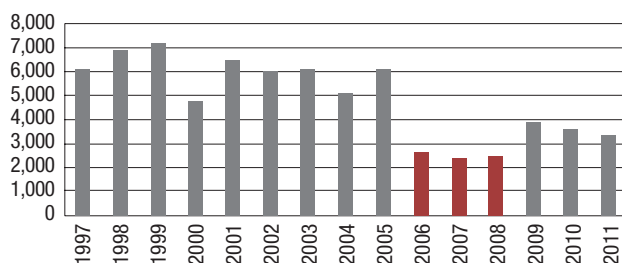
The papers in this issue will present different approaches to the economics of irrigation water in agricultural systems. Economics is relevant to water management, in particular irrigation, because it provides with techniques to assess the impacts of any changes to water management and can provide with instruments to modify the behaviour of water users in order to achieve socially-relevant water management objectives.

Mediterranean regions share common features such as arid and semi-arid climates, hot and dry summers and mild and rainy winters. The relevance of irrigation and water management in Mediterranean agricultural systems arises from the fact that irrigation consumes 64% of water in the region, being even close to 90% in many aquifers and basins. Crop production is highly vulnerable to climate change due to predicted deficits in available water resources and serious farmland degradation threats.

However, despite the similarities in pressures, agriculture within higher-income northern countries faces different problems than in lower-income Southern Mediterranean countries. The papers in this issue focus on the questions that agriculture in developed economies arise, ranging from Israel to Spain. In these Mediterranean countries, irrigated farming accounts for a large share of total water withdrawals (83% in Greece, 68% in Spain, 57% in Italy, and 52% in Portugal; Berbel *et al.*, 2011<sup>1</sup>).

Irrigation in these Mediterranean countries has gone through relevant structural changes during the last two decades. As an illustrative example of these structural

changes, we comment on the recent evolution of irrigated farms in the Guadalquivir basin (South Spain), which cover more than 200,000 ha and can be considered representative of European Mediterranean basins. Figure 1 shows the average gross water usage in the Guadalquivir basin for the last fifteen years. The changes observed, as illustrated in Figure 1, are characteristic of the overall changes occurring in Southern European irrigated areas.



**Figure 1.** Average gross water use ( $\text{m}^3 \text{ha}^{-1}$ ) in large Guadalquivir irrigation schemes. Irrigated area covered 202,305 ha (year 2011, own estimation). Source: Registros del Área de Explotación (Comisión de Desembalse- Confederación Hidrográfica del Guadalquivir, Sevilla)

Figure 1 is based on *Confederación Hidrográfica del Guadalquivir* reports for the years 1997-2010 and own estimation for the campaign 2011. During the period 1997-2005, where the average water use was  $6,100 \text{ m}^3 \text{ha}^{-1}$  farmers, did not suffer water restrictions at all. The 2003 CAP reform was not yet implemented and the process of modernization (irrigation scheme reform) was not initiated. The drought period that followed (2006-2008) resulted in an average water supply of around 50% of the normal water availability and highlights the uncertainty and variability of water supply in Mediterranean basins.

Since 2009, despite a return to ‘normal’ hydrological conditions in the basin, the average water use continued to be lower than the 1997-2005 average at  $3,600 \text{ m}^3 \text{ha}^{-1}$ . There are various factors which may have contributed to the observed reduction in water usage. These include the full implementation of the CAP reform, network improvements and overall modernisation of irrigation schemes, changes to crop patterns and management practices, the

<sup>1</sup> BERBEL J., MESA-JURADO M.A., PISTÓN J.M., 2011. Value of irrigation water in Guadalquivir basin (Spain) by residual value method. *Water Resources Management*.doi: 10.1007/s11269-010-9761-2.

use of deficit irrigation, increase in the cost of water and the introduction of volumetric billing. It is important to identify how each has contributed to the changes observed and which have been most influential.

This subject matter will be explored in the thirteen papers included in this special issue. The first three papers present different approaches to water pricing, using different methodologies to understand the impact of the type and amount of the water tariff instrument in the farmer's water demand. Farmers are a heterogeneous social group with varying personal characteristics (risk aversion, knowledge, etc.) and physical farm features. As a result, different individuals will choose to grow different types of crop as well as using different irrigation technologies.

These first three papers all conclude on the overall inelasticity of water demand, the heterogeneity of farmers and of the estimated value of water. As a consequence, **Esteban *et al.*<sup>2</sup>** suggest the use of a non-uniform tax rate in order to reach a satisfactory reduction in pollution emissions and the change to a more efficient irrigation technology. **Alarcon *et al.*<sup>3</sup>** propose a progressive pricing system with over-consumption sanctions, aimed specifically at each crop, improving the impact of the traditional and widespread single general equalitarian fixed price system. Both approaches have in common the practical barriers to implement complex systems, because they imply a deep knowledge of each agricultural system, crop and technique, and because they require installation of technological equipment to control the water being used by individual farmers.

**Gallego-Ayala *et al.*<sup>4</sup>** employ a different approach to water pricing, in which they analyse the potential consequences of different instruments for irrigation water pricing (area, volumetric, two-part tariff and block-rate) in order to study the impact on the sustainability of irrigated areas. A composite indicator (integrating economic, social and environmental) for each instrument is obtained, and the authors conclude that economic (profitability) and social (employment) sustainability will decline, while only a slight

improvement in environmental sustainability will be obtained. Therefore, we can conclude that the use of water pricing seems to have a reduced impact on water saving on the short run and that the heterogeneity of farming systems requires a specific approach to each case. Nevertheless, the drastic reduction in water use in the Guadalquivir basin shown in Figure 1 maybe partially explained by the growing cost of water abstraction and distribution.

However, an alternative and possibly important explanation is the 'modernisation' of irrigated areas. This involves the adoption of pressurized distribution systems and water saving technologies in a large irrigation scheme. Two papers deal with this technological change. First, **Rodríguez Díaz *et al.*<sup>5</sup>** conclude in their ex-post analysis of this change that, although the amount of water diverted for irrigation to the farms has been considerably reduced, the consumptive use of water has increased, mainly due to a change in crop rotations. The costs for operation and system maintenance have dramatically increased as the energy demanded is much higher now because water and energy became a new set of related variables in these modernized systems.

Also dealing with modernisation, **Gutiérrez-Martín and Gómez<sup>6</sup>** apply a multi-criteria model to study how farmers react by adjusting these decisions when water use efficiency is improved. As in the previous paper, they conclude that potential water savings from enhancing irrigation techniques are overcome by increasing water demand due to higher crop water productivity.

Another factor explaining the observed water saving in Guadalquivir is the new CAP framework where subsidies are decoupled. The impact of CAP changes on water demand is addressed in the paper by **Giannoccaro and Berbel<sup>7</sup>** who analyse the effects of post 2013 CAP scenarios on the irrigated agriculture of several European countries. Reactions to the CAP reforms that influence farmer's decisions on water use will depend on regional differences, amount of subsidies, farm size, farmer's age, and the location of the farm.

<sup>2</sup> ESTEBAN E., TAPIA J., MARTÍNEZ Y., ALBIAC J., 2011. Pigouvian taxation to induce technological change and abate nonpoint pollution in the Ebro Basin. This issue, pp. 957-970.

<sup>3</sup> ALARCON J., MESA-JURADO M.A., BERBEL J., 2011. Design of irrigation water tariffs with overconsumption sanctions. This issue, pp. 971-980.

<sup>4</sup> GALLEGO-AYALA J., GÓMEZ-LIMÓN J.A., ARRIAZA M., 2011. Irrigation water pricing instruments: a sustainability assessment. This issue, pp. 981-999.

<sup>5</sup> RODRÍGUEZ DÍAZ J. A., PÉREZ URRESTARAZU L., CAMACHO POYATO E., MONTESINOS P., 2011. The paradox of irrigation schemes modernization: More efficient water use linked to higher energy demand. This issue, pp. 1000-1008.

<sup>6</sup> GUTIÉRREZ-MARTÍN C., GÓMEZ GÓMEZ C.M., 2011. Assessing irrigation efficiency improvements in agricultural and water policy. This issue, pp. 1009-1020.

<sup>7</sup> GIANNOCCARO G., BERBEL J., 2011. Influence of the Common Agricultural Policy on the farmer's intended decision on water use. This issue, pp. 1021-1034.

Another factor explaining the resilience of Mediterranean agricultural systems is the use of deficit irrigation which is widespread in basins such as the Guadalquivir (Berbel *et al.*, 2011<sup>8</sup>). The paper by Cortignani and Severini<sup>9</sup> applies Positive Mathematical Programming (PMP) to an irrigated area of Italy to evaluate the likely impact of such environmental payments on water use, cropping patterns, adoption of deficit irrigation techniques and economic results on farms. Figure 1 highlights the variability in irrigation supply between the three drought years and non-drought years. High variability in rainfall distribution is a common feature of the Mediterranean climate and influences the availability of green water (rain water available for crops) and blue water (irrigation water).

Climate change (CC) is expected to diminish the availability of water in Mediterranean basins. The uncertainty in water availability is analysed from the point of view of the impact of CC on maize production by Rey *et al.*<sup>10</sup>. This paper analyses the potential impacts of CC on maize's water needs, yield of maize and profitability in Spain. Adaptation as a measure to reduce the negative impacts of CC on maize's yield will generate a lower decrease of evapotranspiration (ET) and future irrigation needs. Moreover, adaptation measures will reduce the variance of both ET and irrigation needs for this period. Thus the efficiency of water use by the maize crop will be greater in all sites in the future. If adaptation is implemented, the effects on this efficiency will depend on the site studied, improving in some regions, and decreasing in others. The future potential of agriculture will depend upon the effects of CC, as irrigation will be impacted by an increase in the variability of rainfall and drought occurrence. Quiroga *et al.*<sup>11</sup> analyse the economic value of drought informa-

tion. If runoff is reduced, farmers can consider contracting hydrological risk insurance in order to eliminate the economic risk associated with water scarcity.

Water use in Mediterranean agricultural systems requires the integration of blue and green water, as suggested by Bielsa *et al.*<sup>12</sup>. They apply a hydro-economic approach to water and land management which includes an analysis of the stability of the green/blue water ratio and the impact of run-off in regions where changes to land cover has occurred. They conclude that the combined management of green and blue water is needed.

Salmoral *et al.*<sup>13</sup> present a paper dealing also with blue and green water by looking at the water footprint of olives and olive oil in Spain. Virtual water related to olive oil exports illustrates the importance of the green water footprint of rain-fed olives.

Finally two relevant issues complete the collection of articles on the economics of irrigation water management in Mediterranean agricultural systems. Latinopoulos *et al.*<sup>14</sup> address the problem of groundwater management with the support of multi-criteria techniques, whereas Pujol *et al.*<sup>15</sup> analyse the cost of reused water.

These thirteen articles aim to provide an up-to-date and relevant overview of the economics of irrigation. Certainly further research is needed on various related issues such as water markets, equity analysis, policy making and governance. However the present selection of papers provides a fairly comprehensive representation of our current understanding of the economics of water in Mediterranean irrigated agricultural systems.

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<sup>8</sup> BERBEL J., MESA-JURADO M.A., PISTÓN J.M., 2011. Value of irrigation water in Guadalquivir basin (Spain) by residual value method. *Water Resources Management*. doi: 10.1007/s11269-010-9761-2.

<sup>9</sup> CORTIGNANI R., SEVERINI S., 2011. Can environmental payments induce farmers' to switch to deficit irrigation and reduce water use? An analysis performed by means of PMP models. This issue, pp. 1035-1046.

<sup>10</sup> REY D., GARRIDO A., MINGUEZ M.I., RUIZ-RAMOS M., 2011. Impact of climate change on maize's water needs and yields and its profitability under various water prices in Spain. This issue, pp. 1047-1058.

<sup>11</sup> QUIROGA S., GARROTE L., IGLESIAS A., FERNÁNDEZ-HADDAD Z., DE LAMA B., MOSSO C., SÁNCHEZ-ARCILLA A., SCHLICKENRIEDER J., 2011. The economic value of drought information for irrigation farmers: a case study in the Ebro basin. This issue, pp. 1059-1075.

<sup>12</sup> BIELSA J., CAZCARRO I., SANCHO Y., 2011. Water and land management in Mediterranean climates: Green versus blue water. This issue, pp. 1076-1088.

<sup>13</sup> SALMORAL G., ALDAYA M.M., CHICO D., GARRIDO A., LLAMAS M.R., 2011. The water footprint of olives and olive oil in Spain. This issue, pp. 1089-1104.

<sup>14</sup> LATINOPOULOS D., THEODOSSIOU N., LATINOPOULOS P., 2011. Combined use of groundwater simulation and multi-criteria analysis within a spatial decision-making framework for optimal allocation of irrigation water. This issue, pp. 1105-1119.

<sup>15</sup> PUJOL J., DURAN-ROS M., ARBAT G., RAMÍREZ DE CARTAGENA F., PUIG-BARGUÉS J., 2011. Private micro-irrigation costs using reclaimed water. This issue, pp. 1120-1129.